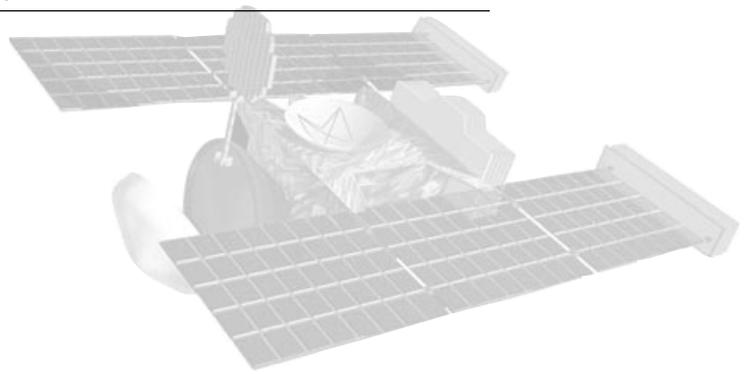


# Fact Sheets

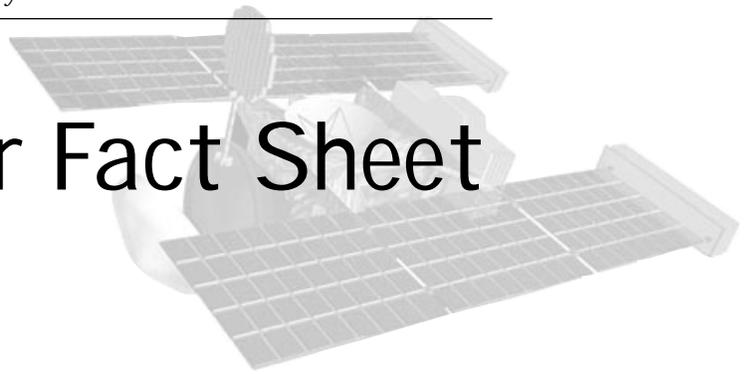


**T**his section contains Fact Sheets for specific activities. They contain background information about comets and the STARDUST mission. Teachers are encouraged to use Fact Sheets as student handouts to support any activity deemed appropriate.

## **The Fact Sheets included are:**

- ◆ Impact Crater Fact Sheet
- ◆ Comet Fact Sheet
- ◆ Kuiper Belt/Oort Cloud Fact Sheet
- ◆ STARDUST Mission Fact Sheet
- ◆ Aerogel Fact Sheet

# Impact Crater Fact Sheet



## What is an Impact Crater?

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Impact craters are marks found on every solid body in the Solar System, like planets and moons. Even asteroids are pitted with craters. When an object slams into a planet, it hits the surface very hard and explodes. Rock and dust fly everywhere. The object that hits the planet is called an impactor. The impactor breaks apart because of the force of the impact, and the impact explosion leaves a round hole or crater in the surface of the planet.

## Crater Parts

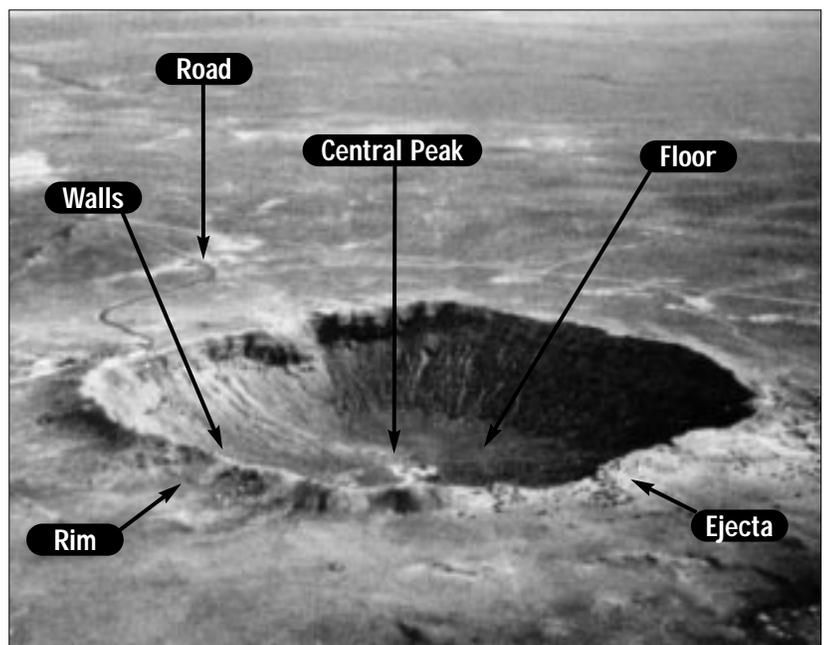
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**Walls**-The sides of the bowl. Walls can be very deep. They may look like steps, or walls can be shallow. If a crater has shallow walls, then the hole was filled or eroded somehow.

**Floor**-The bottom part of the impact site (the hole). It may be the shape of a bowl, or it may be flat. This part is often lower than the surrounding surface.

**Rim**-The highest point along the edge of the hole.

**Ejecta**-The debris that shoots, or ejects, out of the impact site when the crater forms. There is a lot of ejecta close to the crater, so it is thick. The ejecta gets thinner the farther away it is from the crater. The explosion creates debris as it crushes, heats, and melts the rock.



This image shows the Barringer Crater (commonly called Meteor Crater), which is located in the state of Arizona. The crater is 1.2 km across. It is the best preserved crater in North America.

**Rays**-The bright streaks that start at the rim of the crater and extend outward.

**Central Peak**-A small mountain that forms at the center of the crater in reaction to the force of the impact. Only really large craters, typically more than 40 km across, can have a central peak. These craters are the size of large cities.



### What Changes the Shape of a Crater?

Initially craters have a crisp rim and blankets of ejecta around the sides. The actions of wind, water, lava flows, and plate tectonics can alter the appearance of a crater. Wind can blow away debris around the crater. Rivers and floods can erode the crater's walls and rim. Lava flows can fill in the crater and make the rim smoother. Another impactor may come along and give the crater its own crater. Other impactors can partially or completely destroy an older crater.

### Craters and Surface Age

The older a surface is, the more time impactors have to hit it. Really old surfaces have so many craters that it would be difficult to tell if another impactor hit them. Little of the surface is smooth. Most cratering took place right after the planets and moons formed. Places like Earth's Moon and the planet Mercury have heavily cratered, old surfaces.

Younger surfaces have smoother, less cratered surfaces. What makes the surfaces smoother? You will find out one

cause in the activity Go with the Flow. Earth has few craters, due to the features and processes on our planet. Plates that make up Earth's crust move, causing volcanoes or forming mountains. This and other processes erase signs of craters here on Earth and on other planets and moons.

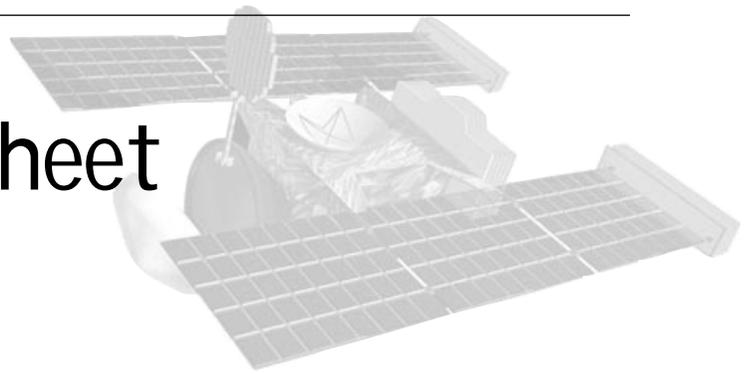
Many worlds have surfaces of different ages. Parts of our Moon are heavily cratered. Other parts are smoother, because lava flows have erased the craters. The ages of the different parts of a planet's surface can be estimated by the number of craters on it.

### What Are Comets?

A common theory about comets is that they are dirty snowballs of frozen ices and rock. We know they contain water ice, frozen carbon dioxide, ammonia and methane ice, rocky materials, and organic (carbon-based) materials. Some scientists think that the center, or **nucleus**, of a comet is solid. Others think the nucleus is not solid enough for a spacecraft landing. There is much about comets we do not know.



# Comet Fact Sheet



## Why Study Comets?

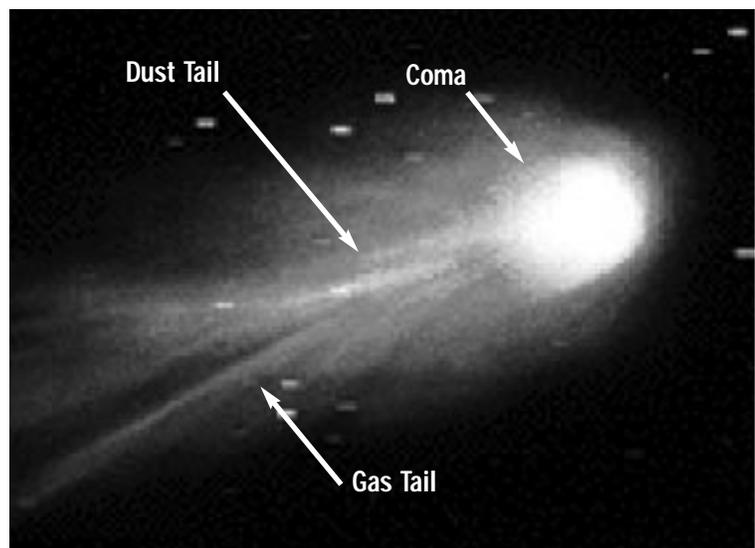
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Comets interest scientists because they are the oldest, most primitive objects in the Solar System. They are remnants from the nebula which formed our Solar System. These remnants may have served as building blocks in the formation of planets in our Solar System as well as around other stars. They are organically rich, providing ready-formed molecules that could originate life. The volatile elements (ices) comets contain can play a role in forming atmospheres and oceans. In addition, a high-velocity impact may cause major changes in atmospheres and affect ecosystems, possibly including the extinction of the dinosaurs. Scientists want to study particles from these cosmic travelers more closely for information that can shed light on the formation of Earth, our Solar System, and other planetary systems.

## Comet Orbits

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Most comets follow long, eccentric orbits around the Sun, spending most of their time traveling in the outer reaches of our Solar System. Comets traveling beyond Jupiter's orbit are usually tailless and difficult to see. Once the comet reaches the inner Solar System, the heat from the Sun begins to make the icy materials **sublime** (turn from solid ice to gas).



Comet Halley

## Parts of a Comet

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The Sun's heat causes dust, small rocky particles, and gas to form a bright, spherical cloud, the **coma**, around the dark **nucleus**. Scientists currently think that the nuclei of most comets are generally the size of a city. Charged particles streaming from the Sun in the solar wind "blow" the coma of the comet, pushing it away from the Sun, forming two **tails**, a yellowish dust tail and a blue tail of gas particles.



### Where Do Comets Originate?

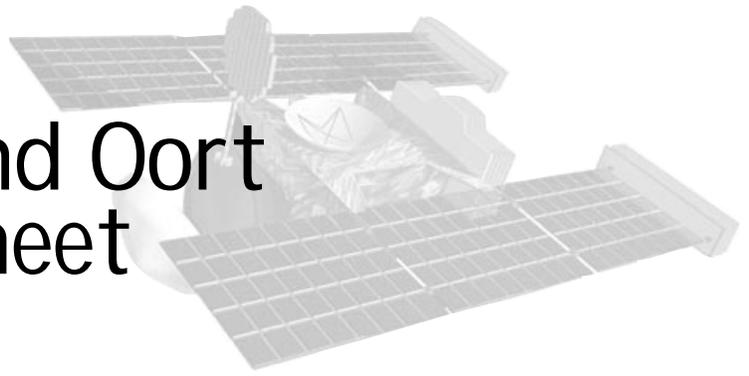
Comets reside in an area past the orbit of Neptune and Pluto in the Kuiper Belt. They are so far away and so small and dark that astronomers have difficulty detecting them. Occasionally, a gravitational disturbance causes one of these bodies to begin a long journey toward the inner Solar System, orbiting the Sun.

The orbit of a comet can be altered by the gravitational field of Jupiter. When this

happens the comet's original orbit of hundreds or thousands of years changes paths, and shortens. Such a comet might end up catapulting into the Sun, get flung out of the Solar System entirely, or hit Jupiter like comet Shoemaker-Levy 9 did in 1994. Jupiter's gravitational pull commonly shortens a comet's orbit, bringing it into the inner Solar System more often. Comet Wild 2 (pronounced "Vilt," after the Swiss astronomer Paul Wild) is such a comet.



# Kuiper Belt and Oort Cloud Fact Sheet

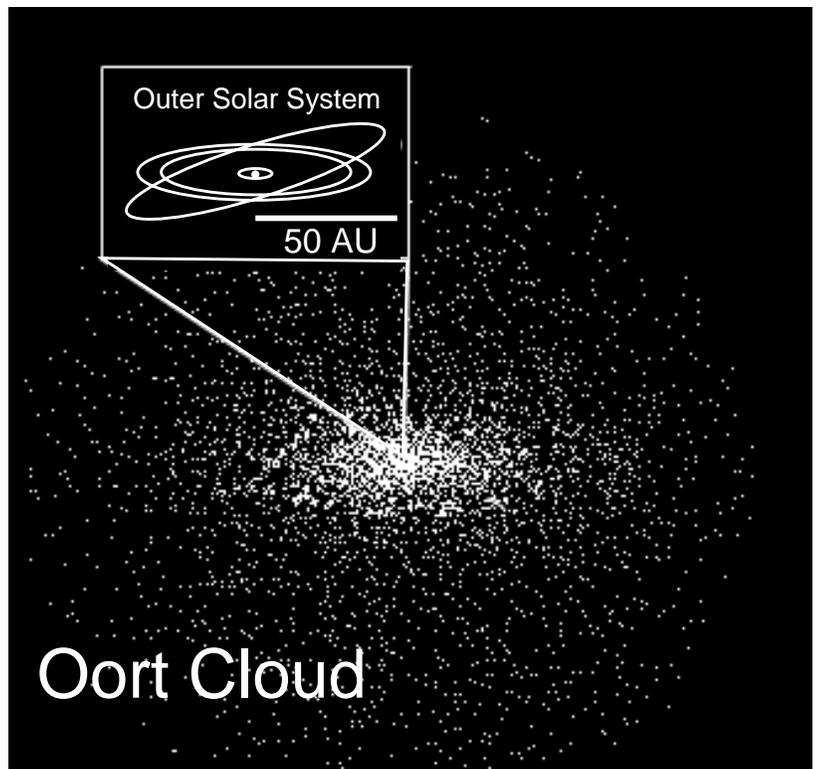


## What Is the Kuiper Belt?

The Kuiper Belt is a belt of asteroids on the outer reaches of the solar system. In 1951, Gerard Kuiper proposed the theory that there is a disk-shaped region past the orbit of Neptune roughly 30-100 AU from the Sun containing small, icy bodies. Only a few objects have been found in it, but it may contain millions of chunks of planetary debris.

The Kuiper Belt holds significance for the study of the planetary system on at least two levels. First, it is likely that the Kuiper Belt objects are extremely primitive remnants from the early accretional phases of the solar system. Second, it is widely believed that the Kuiper Belt is the source of short-period comets. Short-period comets have orbital periods of less than 200 years. The Kuiper Belt acts as a reservoir for these bodies in the same way that the Oort Cloud acts as a reservoir for the long-period comets.

Occasionally, the orbit of a Kuiper Belt object will be disturbed by the interactions of the giant planets in such a way that the object crosses the orbit of Neptune. It will then very likely have a close encounter with Neptune sending it out of the Solar System or into an orbit crossing those of the other giant planets or even into the inner Solar System.



The Oort Cloud is a place where comets originate. An AU is an astronomical unit, the distance from Earth to the Sun.



## What is the Oort Cloud?

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In 1950, Jan Oort noted that no comet has been observed with an orbit that indicates it came from interstellar space, there is a strong tendency for aphelia of long-period comet orbits to lie at a distance of about 50,000 AU, and there is no preferential direction from which comets come. He proposed that comets reside in a vast cloud at the outer reaches of the Solar System. This became known as the Oort Cloud and is a spherical cloud of ice. Long-period comets, those having orbital periods greater than 200 years, were once thought to have fallen into the inner Solar System where the Sun would heat the ice and it would transform into a comet.

Statistics imply that the Oort Cloud may contain as many as one trillion

comets and may account for a significant fraction of the mass of the Solar System. Unfortunately, since the individual comets are so small and at such large distances, we have no direct evidence about the Oort Cloud.

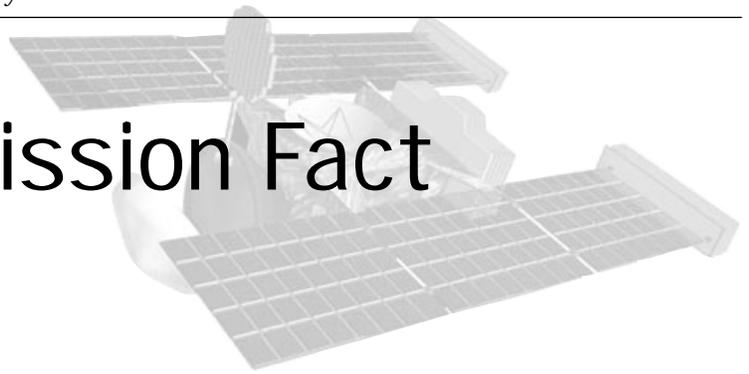
## Differences in Object Formation

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It seems that the Oort Cloud objects were formed closer to the Sun than the Kuiper Belt objects. Small objects formed near the giant planets would have been ejected from the Solar System by gravitational encounters. Those that didn't escape entirely formed the distant Oort Cloud. Small objects formed farther out had no such interactions and remained in the Kuiper Belt.



# STARDUST Mission Fact Sheet



## The STARDUST Mission

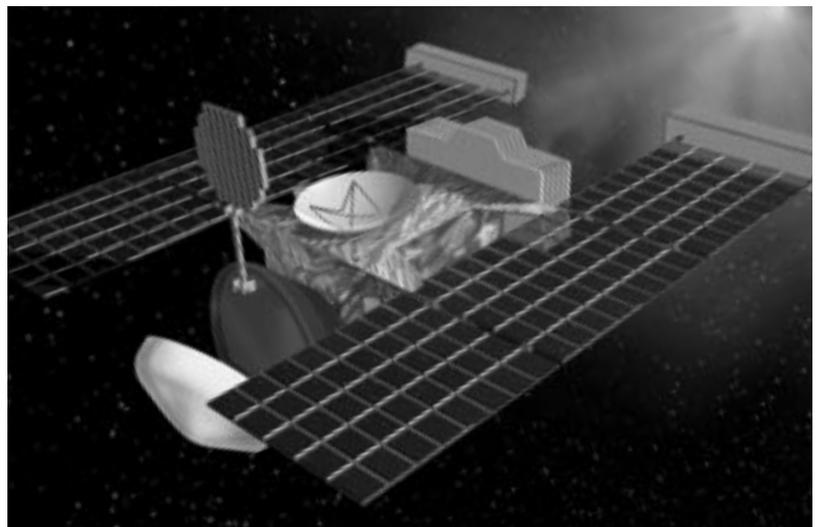
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STARDUST is a small spacecraft that will rendezvous with Comet Wild 2, (pronounced "Vilt" after its Swiss discoverer professor Paul Wild) in 2004. It is the first spacecraft to capture and return cometary dust to Earth for analysis. The spacecraft was launched in February 1999 on board an expendable launch vehicle and rendezvous with Comet Wild 2 in January 2004, coming within 150 kilometers (93 miles) of the comet's nucleus. The particles STARDUST will return are made of ancient material that formed our Sun and planets. What we learn about Comet Wild 2 will probably reshape our understanding of how our Solar System—and perhaps even life—formed.

## Comet Wild 2

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Jupiter changed Comet Wild 2's orbit in 1974 when the comet made a close approach to the gas giant. A predictable six-year orbit made Wild 2 a good target for the STARDUST mission. Also, Wild 2 is a pristine comet - one that is close to its



original state. Every time a comet travels near the Sun it loses gas and dust. Wild 2 will only have made 5 passes around the Sun by the time STARDUST reaches it. The fewer the passes a comet makes near the Sun, the less altered it is from its original state. The more pristine a comet is, the more clues it may reveal to scientists about the formation of the Solar System and possibly life itself.



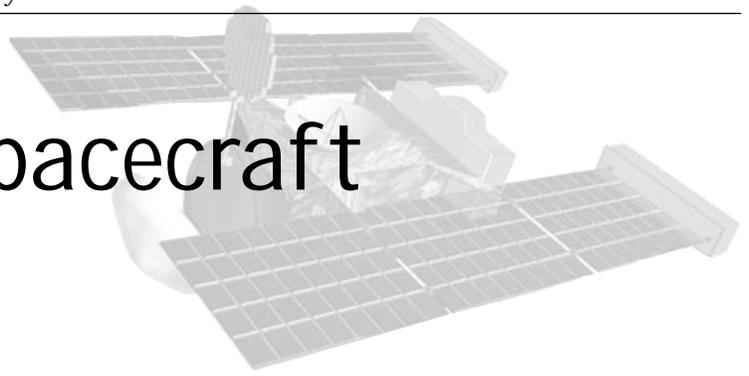
## Key STARDUST Dates

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<b>1974</b>	<b>Comet Wild 2 orbit altered by Jupiter, bringing it into the inner Solar System in pristine condition</b>
<b>January 1978</b>	<b>Paul Wild discovers Comet Wild 2</b>
<b>1995</b>	<b>NASA selects STARDUST mission</b>
<b>February 1999</b>	<b>STARDUST Launch</b>
<b>March 2000 - May 2000</b>	<b>First Interstellar Dust Collection</b>
<b>January 2001</b>	<b>Earth flyby</b>
<b>July 2002 - December 2002</b>	<b>Second Interstellar Dust Collection</b>
<b>January 2004</b>	<b>Wild 2 Encounter</b>
<b>January 2006</b>	<b>Sample Return Capsule returns to Earth</b>



# STARDUST Spacecraft Fact Sheet



The STARDUST spacecraft is small, measuring the 1.7 meters in length - about the size of an average teacher's desk. Its total weight is 380 kilograms - about the weight of a subcompact car - including propellant needed for space maneuvers. The parts of the spacecraft fall into two categories: science instruments or spacecraft operations.

## SCIENCE INSTRUMENTS

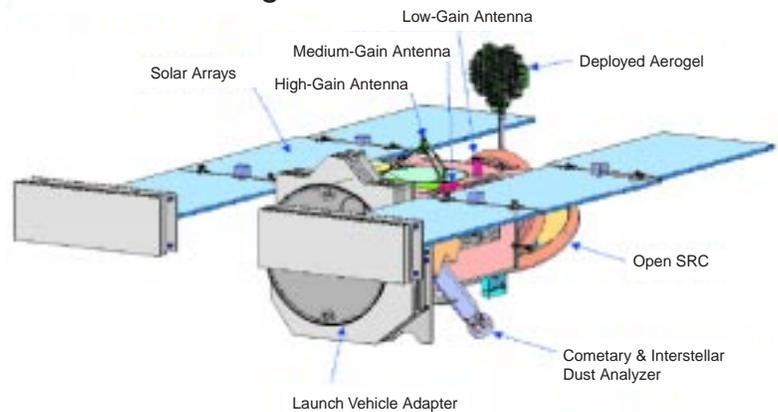
### Aerogel Dust Collector

The dust collector is a two-sided, aluminum tube grid array that deploys from the Sample Return Capsule. The grid contains blocks of aerogel that are 1 to 2 centimeters thick. Aerogel, also known as "blue smoke" or "solid smoke," is a strong, lightweight, exotic material with the lowest density of any solid. Aerogel is 99% air and 1% silicate dioxide (similar to glass).

When the STARDUST spacecraft flies through the coma, or head, of the comet, the collector will deploy from the Sample Return Capsule (SRC). Cometary particles will hit the aerogel at nearly 6 times the speed of a rifle bullet. The aerogel traps these cosmic bullets without damaging them.

The dust collector will deploy four separate times throughout the seven-year mission. One side will collect interstellar

### Encounter Configuration



STARDUST Spacecraft

dust and the other side will collect comet particles.

### Sample Return Capsule (SRC)

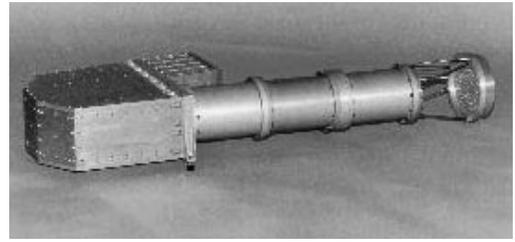
The SRC stores the samples of comet particles and interstellar dust. It separates from the spacecraft just before encountering Earth. The heat shields protect the capsule from burning up when the SRC reenters Earth's atmosphere. Three kilometers from hitting the ground, a two-part parachute system opens. The capsule will gently touch down in a dry lake bed in Utah, where it will be retrieved and the samples studied.



## Cometary and Interstellar Dust Analyzer (CIDA)

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The CIDA is a mass spectrometer. It analyzes the chemicals found in the comet and interstellar dust when they enter the instrument. Once a particle enters the CIDA, it separates into smaller pieces. The heavier pieces move more slowly than the lighter pieces do, passing sensors at different times. The difference in flight time allows scientists to calculate the mass of the particle.



Cometary and Interstellar Dust Analyzer

## SPACECRAFT OPERATIONS

All other instruments on board operate the spacecraft. These include:

- ◆ Navigation Camera,
- ◆ Dust Flux Monitors,
- ◆ Solar Array Panels, and
- ◆ three antennas.

### Navigation Camera (NC)

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The camera navigates the approach to the comet for proper flyby distance. The challenge is to get near the nucleus to collect enough dust. The camera periscope can look over the dust shield during the approach. A scanning mirror rotates to keep the comet in view during flyby. This rotating mirror is some distance from the actual camera lens. The forward-looking mirror has a thick aluminum coating to protect it from impacting particles. The mirror facing away from the particle stream has a nickel coating that produces better images, but flakes off during particle impacts.

The camera also takes pictures through colored filters. These images will help scientists construct a 3-D map of the comet nucleus, and identify gases jetting from

the nucleus. The NC is mounted on a platform called the deep space bus. Layered, metallic-gold blankets protect the sensitive instruments from the extreme temperatures of space and impacts.

### Dust Flux Monitors

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Three dust shields protect the spacecraft. They use small vibration sensors to detect large impacting particles. The monitors will determine how hazardous particles from the first encounter with the comet will be.

### Solar Arrays

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Two wing-like solar array panels power the spacecraft. The arrays are long, lightweight grids containing thousands of solar cells, which tilt to face the Sun. Solar cells are thin, circular wafers that create electricity when light shines on them.

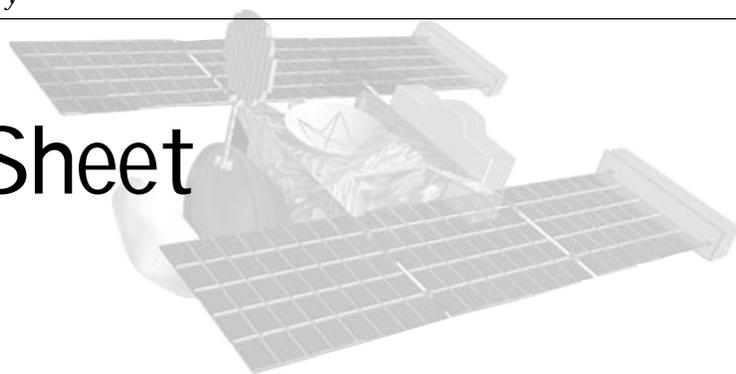
### Antennae

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STARDUST has three antennas to transmit and receive data. In addition to comet data, the antennas will transmit commands from mission control to navigate and operate the spacecraft. The high-gain antenna sends the most data in the shortest amount of time. If one antenna should fail, mission control will still be able to communicate with the spacecraft.



# Aerogel Fact Sheet



At first sight, aerogel resembles a hologram. It is commonly called “blue smoke” or “solid smoke.” This exotic material has the lowest density of any known solid: it is 99% air. It is 1,000 times less dense than glass. The other percent is made of silica dioxide, a substance used to make glass.

Amazingly lightweight and strong, a block of aerogel the size of a human may weigh less than half a kilogram (less than a pound), yet support the weight of a subcompact car (about 454 kilograms, or 1,000 pounds). An inch of aerogel has the same insulating power as 6 inches of fiberglass and can withstand temperatures up to 1,400° C (2,552° F).

In the photo, scientist Peter Tsou holds a block of aerogel that he made by hand. Aerogel starts as a silica dioxide gel, similar to gelatin you might eat. A process called supercritical drying removes the liquid without collapsing the gel.

When the STARDUST spacecraft flies through the comet’s coma, the cometary particles will hit the aerogel at hypervelocities up to 6 times the speed of a rifle bullet. Aerogel will trap these cosmic bullets, keeping them intact so they are not damaged by the impact.

## Particle Tracks

When hypervelocity particles are captured in aerogel they produce narrow, cone-shaped, hollow tracks in the highly transparent aerogel. The cone is largest where the particle entered the aerogel.

Scientists follow the cone to its point to collect the intact particle. The conical tracks indicate the direction which the particles were traveling when they entered the aerogel. In this image, the particle entered the aerogel from the bottom right and stopped in the upper left corner.

